

5 FIELD OF THE INVENTION

## BACKGROUND OF THE INVENTION

30 In conventional type multi-domain vertically aligned mode liquid crystal displays, it is necessary that bumps or slits are formed on the transparent common electrode in the color filter side substrate, which required one excessive photo mask process. Therefore, in this conventional technology, cost increase is unavoidable.

Moreover, in vertically aligned mode liquid crystal displays with bumps 5 formed in the color filter layer 3 side, as shown in Fig. 1, when a width, a pitch, and an angle of the slope of the bumps 5 are not precisely controlled, variation in the tilting degree of liquid crystal molecules 14 is occurred, which frequently causes unevenness in half tone area.

Since bumps are made of positive type photoresists, perfect removal of organic solvents, and furthermore hardening by baking at high temperatures of no less than 200 degrees are furthermore required, leading difficulty in shortening the processes. When contaminants are eluted out into liquid crystals from the bumps of positive type photoresists, a phenomenon of afterimage will occur, resulting in reliability problems.

In color filter substrates using the conventional bumps, positive type photoresists are used as materials for the bumps, and therefore, when a defect occurs in the application process of a vertical alignment film 6 and reworking is required, a dry ashing method using oxygen plasma can not be used. Therefore, a wet remove method requiring high running cost using organic solvents has to be used, which causes a disadvantage requiring a very high reworking cost.

In vertically aligned mode liquid crystal displays using the conventional type bumps and slits, when a display switchovers to a half tone display from a black display, or to a half tone display from a white display, there arises defects that the liquid crystals operate in a slow response speed.

#### SUMMARY OF THE INVENTION

The present invention has been made to solve the above-mentioned problems, and it is an object of the present

invention to improve reliability of a large-sized vertically aligned mode liquid crystal display.

5 It is also an object of the present invention to provide a large-sized vertically aligned mode liquid crystal display that can be manufactured at low cost in a short time, while having capability of high brightness and high response speed.

10 In order to solve the problems in the conventional technology and to achieve the above-mentioned objects, following methods are used in the present invention.

[Method 1]

15 In order to impress a voltage to anisotropic liquid crystal molecules that are vertically aligned to an active matrix substrate and a color filter substrate and have a negative dielectric constant, and to make the liquid crystal molecules tilt in different two directions or four directions, two kinds of following electrode structures were formed in one pixel of the active matrix substrate.

20 i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns (no transparent electrode in a slit part) having a shape of a long and slender slit are formed.

25 ii) a transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, two rows of liquid crystal alignment direction control electrodes that are mutually separated and set as potentials different from each other exist in a lower layer of the transparent pixel electrode via an insulated film, either of the liquid crystal alignment direction control electrodes have almost the same  
30 shape as a shape of a pattern of the shape of long and  
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slender slits, and a larger dimension than a dimension of the slit; and two rows of the liquid crystal alignment direction control electrodes mutually separated are arranged in a direction of a scan signal wire in a lower layer of the long and slender slits that are formed, mutually exchanged in an every fixed pixel cycle, in the transparent pixel electrode.

[Method 2]

A following drive system is used as a method for driving the vertically aligned mode liquid crystal display having the electrode structure by the method 1.

There is used a drive system in which: when a potential of the transparent pixel electrode separated for every pixel of an active matrix substrate side is lower than a potential of the counteracting flat common electrode on a color filter substrate side, a potential of the liquid crystal alignment direction control electrode currently placed in a lower layer of the slit of the transparent pixel electrode is set lower than a potential of the transparent pixel electrode; and when a potential of the transparent pixel electrode is higher than a potential of the counteracting flat common electrode of the color filter substrate side, a potential of the liquid crystal alignment direction control electrode placed in a lower layer of the slit of the transparent pixel electrode is set higher than a potential of the transparent pixel electrode, and potentials of the liquid crystal alignment direction control electrodes arranged in the vicinity of both sides of the scan signal wiring are set as polar potentials different from each other, and polarities of the potential of the transparent pixel electrode, and each of the potential of the two rows of the liquid crystal alignment direction control electrodes mutually separated in one pixel are reversed to a polarity of a polarity of the potential of the flat common electrode in a color filter substrate side every vertical scanning period.

[Method 3]

5 In a color active matrix type vertically aligned mode liquid crystal display in which adjacent transparent pixel electrodes in a direction of a scan signal wiring are connected to a thin film transistor component controlled by mutually different scan signal wirings, in order to impress a voltage to liquid crystal molecules that are vertically aligned between an active matrix substrate and a color filter substrate and to make the liquid crystal molecules tilt in different two directions or different four directions, two kinds of following electrode structures were formed in one pixel of the active matrix substrate.

10 i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns (no transparent electrode in a slit part) having a shape of a long and slender slit are formed.

15 ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, and a liquid crystal alignment direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit are formed in a lower layer of the slit via an insulated film.

[Method 4]

20 A following drive system is used as a method for driving the vertically aligned mode liquid crystal display having the electrode structure by the method 3.

25 There is used a drive system in which: when a potential of the transparent pixel electrode separated for every pixel of an active matrix substrate side is lower than a potential of the countering flat common electrode on a color filter

substrate side, a potential of the liquid crystal alignment direction control electrode currently placed in a lower layer of the slit of the transparent pixel electrode is set lower than a potential of the transparent pixel electrode; and when a potential of the transparent pixel electrode is higher than a potential of the countering flat common electrode of the color filter substrate side, a potential of the liquid crystal alignment direction control electrode placed in a lower layer of the slit of the transparent pixel electrode is set higher than a potential of the transparent pixel electrode; and polarities of the potential of the transparent pixel electrode, and of the potential of the liquid crystal alignment direction control electrode are reversed to a polarity of a potential of the flat common electrode in a color filter substrate side every vertical scanning period.

[Method 5]

In order to impress a voltage to anisotropic liquid crystal molecules that are vertically aligned to an active matrix substrate and a color filter substrate and have a negative dielectric constant, and to make the liquid crystal molecules tilt in many directions, two kinds of following electrode structures were formed in one pixel of the active matrix substrate.

i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode on the active matrix substrate side, many circular or polygonal holes (no transparent electrodes in a portion of a hole) are formed.

ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, two rows of liquid crystal



alignment direction control electrodes that are mutually separated and set as potentials different from each other exist in a lower layer of the transparent pixel electrode via an insulated film, either of the liquid crystal alignment direction control electrodes has almost the same shape as a shape of a pattern of the shape of long and slender slits, and a larger dimension than a dimension of the slit, and two rows of the liquid crystal alignment direction control electrodes mutually separated are arranged in a direction of a scan signal wiring in a lower layer of the long and slender slits that are formed, mutually exchanged in an every fixed pixel cycle, in the transparent pixel electrode.

[Method 6]

A following drive system is used as a method for driving the vertically aligned mode liquid crystal display having the electrode structure by the method 5.

There is used a drive system in which: when a potential of the transparent pixel electrode separated for every pixel of an active matrix substrate side is lower than a potential of the countering flat common electrode on a color filter substrate side, a potential of the liquid crystal alignment direction control electrode currently placed in a lower layer of a slit of the transparent pixel electrode is set lower than a potential of the transparent pixel electrode; and when a potential of the transparent pixel electrode is higher than a potential of the countering flat common electrode of the color filter substrate side, a potential of the liquid crystal alignment direction control electrode placed in a lower layer of the slit of the transparent pixel electrode is set higher than a potential of the transparent pixel electrode; and potentials of the liquid crystal alignment direction control electrodes arranged in the vicinity of both sides of the scan signal wiring are set as polar potentials different from each other, and polarities

of the potential of the transparent pixel electrode, and of each of the potential of the two rows of the liquid crystal alignment direction control electrodes mutually separated in one pixel are reversed to a polarity of a potential of the flat common electrode in a color filter substrate side every  
5 vertical scanning period.

[Method 7]

In an active matrix type vertically aligned mode liquid crystal display in which adjacent transparent pixel  
10 electrodes in a direction of a scan signal wiring are connected to a thin film transistor component controlled by mutually different scan signal wirings, in order to impress a voltage to liquid crystal molecules that are vertically aligned between an active matrix substrate and a color  
15 filter substrate and to make the liquid crystal molecules tilt in many directions, two kinds of following electrode structures were formed in one pixel of the active matrix substrate.

i) A transparent flat common electrode is used in a color  
20 filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, many circular or polygonal holes (no transparent electrodes in a portion of a hole) are formed.

ii) A transparent flat common electrode is used in a color  
25 filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, a liquid crystal alignment  
30 direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit are formed in a lower layer of the slit via an insulated film.

[Method 8]



A following drive system is used as a method for driving the vertically aligned mode liquid crystal display having the electrode structure by the method 7.

5        There is used a drive system in which: when a potential of the transparent pixel electrode separated for every pixel on an active matrix substrate side is lower than a potential of the countering flat common electrode on a color filter substrate side, a potential of the liquid crystal alignment direction control electrode currently placed in a lower layer of a slit of the transparent pixel electrode is set  
10       lower than a potential of the transparent pixel electrode; and when a potential of the transparent pixel electrode is higher than a potential of the countering flat common electrode of the color filter substrate side, a potential of  
15       the liquid crystal alignment direction control electrode placed in a lower layer of the slit of the transparent pixel electrode is set higher than a potential of the transparent pixel electrode; and polarities of the potential of the transparent pixel electrode, and of the potential of the  
20       liquid crystal alignment direction control electrode are reversed to a polarity of a potential of the flat common electrode in a color filter substrate side every vertical scanning period.

[Method 9]

25       In the method 1 and 3, the slit formed in the transparent pixel electrode in an active matrix substrate side and extending long and slender, and the slit forming a group with the liquid crystal alignment direction control electrode are arranged alternately, maintaining an almost  
30       parallel relationship in a direction making about  $\pm 45$  degrees to a direction of the scan signal wiring; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of

the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 10]

5 In the method 1 and 3, there was adopted a structure that the slit formed in the transparent pixel electrode in an active matrix substrate side and extending long and slender is arranged in a direction making  $\pm 45$  degrees to a direction of a scan signal wiring; and the slit forming a group with the liquid crystal alignment direction control electrode are arranged in a parallel direction and in a perpendicular direction to a direction of the scan signal wirings; and the liquid crystal alignment direction control electrode encloses a periphery of the transparent pixel electrode while overlapping with the transparent pixel electrode via the insulated film; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in the direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 11]

25 In the method 1 and 3, there was adopted a structure that the slit formed in a transparent pixel electrode in an active matrix substrate side and extending long and slender is arranged in a parallel direction and in a perpendicular direction to the direction of the scan signal wiring; and the slit forming a group with the liquid crystal alignment direction control electrode is arranged in parallel to a direction of the scan signal wiring; and the liquid crystal alignment direction control electrode encloses a periphery of the transparent pixel electrode while overlapping with the transparent pixel electrode via the insulated film; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged a direction of the scan signal wiring and in a direction of the video

signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 12]

5 In the method 1 and 3, the slit formed in a transparent pixel electrode in an active matrix substrate side and extending long and slender is arranged in a parallel direction and in a perpendicular direction to a direction of the scan signal wiring; and the slit forming a group with the liquid crystal alignment direction control electrode  
10 have a structure arranged in directions making  $\pm 45$  degrees to a direction of the scan signal wiring; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and  
15 are arranged so that they may perpendicularly mutually intersect.

[Method 13]

In the method 5 and 7, there was adopted a structure that the slit forming a group with the liquid crystal alignment direction control electrode are arranged in a  
20 parallel direction and in a perpendicular direction to a direction of the scan signal wiring so as to enclose two or more of circular or polygonal holes currently formed in the transparent pixel electrode in an active matrix substrate side; and the liquid crystal alignment direction control electrode encloses a periphery of the transparent pixel electrode while overlapping with the transparent pixel electrode via the insulated film; and polarization axes of two polarizing plates placed in exterior of a liquid crystal  
25 cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 14]

5 In the method 1, 3, 5, and 7, the liquid crystal alignment direction control electrode formed in a lower layer of the slit of the transparent pixel electrode via the insulated film is simultaneously formed in the same layer at the time of formation of the scan signal wiring.

[Method 15]

10 In the methods 1, 3, 5, and 7, an additional capacitance was formed with the liquid crystal alignment direction control electrode formed in a lower layer of the slit of the transparent pixel electrode via the insulated film, and the transparent pixel electrode.

[Method 16]

15 In the method 1 and 5, all of the scan signal wirings and the liquid crystal alignment direction control electrodes are completely separated, and are connected to output terminals of different drive ICs, respectively; and contact buttons of the two rows of liquid crystal alignment direction control electrodes for controlling one row of pixels are arranged so that they may be sandwiched between contact buttons of different scan signal wirings.

20 [Method 17]

25 In the method 3 and 7, all of the scan signal wirings and the liquid crystal alignment direction control electrodes are completely separated and independent, and are connected to output terminals of different drive ICs, respectively; and contact buttons of the one row of liquid crystal alignment direction control electrodes for controlling one row of pixels are arranged so that they may be sandwiched between contact buttons of different scan signal wirings.

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[Method 18]

35 In the method 1, 3, 5, and 7, contact buttons of the scan signal wiring are arranged in either of right side or left side of a display screen part, and contact buttons of the liquid crystal alignment direction control electrode are

arranged on another side different from a side of the contact buttons of the scan signal wiring, each contact button is mutually completely separated and independent, and is connected to output terminals of different drive ICs, respectively.

[Method 19]

In the method 1 and 5, the scan signal wirings and the liquid crystal alignment direction control electrodes are completely separated and independent, each contact button is arranged on both of right and left sides of a display screen part, and contact buttons of the two rows of the liquid crystal alignment direction control electrodes for controlling one row of pixels are arranged so that they may be sandwiched between contact buttons of different scan signal wirings.

[Method 20]

In the method 3 and 7, all of scan signal wirings and liquid crystal alignment direction control electrodes are completely separated and independent, each contact button is arranged on both of right and left sides of a display screen part, and contact buttons of the one row of liquid crystal alignment direction control electrodes for controlling one row of pixels are arranged so that they may be sandwiched between contact buttons of different scan signal wirings.

[Method 21]

In the methods 2, 4, 6, and 8, at the time of moving image displaying, a bias voltage impressed between the liquid crystal alignment direction control electrode currently formed in a lower layer of the slit of the transparent pixel electrode and the transparent pixel electrode is set higher than a voltage at the time of still picture displaying, and thereby, a tilting speed of anisotropic liquid crystal molecules having a negative dielectric constant are set higher.

[Method 22]

In order to impress a voltage to anisotropic liquid crystal molecules having a negative dielectric constant that are vertically aligned to an active matrix substrate and a color filter substrate and to make the liquid crystal molecules tilt in different two directions or different four directions, two kinds of following electrode structure and structure arrangement were formed in one pixel of the active matrix substrate.

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i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns (no transparent electrode in a slit part) having a shape of a long and slender slit are formed.

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ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, and a liquid crystal alignment direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit are formed in a lower layer of the slit via an insulated film.

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iii) In a pixel of  $n$  row  $m$  column, a thin film transistor element is formed in a position where a scan signal wiring of  $(n-1)$  row and a video signal wiring of  $(m+1)$  column intersect with each other, and a video signal wiring of  $(m+1)$  column and a liquid crystal alignment direction control electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element; and a thin film transistor element is formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect, and a video signal wiring of  $m$  column and a transparent pixel electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element.

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[Method 23]

In order to impress a voltage to anisotropic liquid crystal molecules having a negative dielectric constant that are vertically aligned to an active matrix substrate and a color filter substrate and to make the liquid crystal molecules tilt in different two directions or different four directions, two kinds of following electrode structure and structure arrangement were formed in one pixel of the active matrix substrate.

10 i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns (no transparent electrode in a slit part) having a shape of a long and  
15 slender slit are formed.

ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a  
20 long and slender slit are formed, and a liquid crystal alignment direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit is formed in a lower layer of the slit via an insulated film.

25 iii) In a pixel of  $n$  row  $m$  column, a thin film transistor element is formed on a scan signal wiring of  $(n-1)$  row, a common electrode of  $n$  row, and a liquid crystal alignment direction control electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element,  
30 and a thin film transistor element is formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the video signal wiring of  $m$  column, and a transparent pixel electrode used for a pixel of  $n$  row  $m$  column are connected via the  
35 thin film transistor element.

[Method 24]

5 In order to impress a voltage to liquid crystal molecules that are vertically aligned to an active matrix substrate and a color filter substrate and to make the liquid crystal molecules tilt in many directions, two kinds of following electrode structure and structure arrangement were formed in one pixel of the active matrix substrate.

10 i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, circular or polygonal holes (no transparent electrodes in a portion of a hole) are formed.

15 ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, a liquid crystal alignment direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit are formed in a lower layer of the slit via the insulated film.

20 iii) In a pixel of  $n$  row  $m$  column, a thin film transistor element is formed in a position where a scan signal wiring of  $(n-1)$  row and a video signal wiring of  $(m+1)$  column intersect with each , and a video signal wiring of  $(m+1)$  column and a liquid crystal alignment direction control electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element; and a thin film transistor element is formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the video signal wiring of  $m$  column and a transparent pixel electrode used for pixel of  $n$  row  $m$  column are connected via the thin film transistor element.

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[Method 25]

In order to impress a voltage to liquid crystal molecules that are vertically aligned between an active matrix substrate and a color filter substrate and to make the liquid crystal molecules tilt in many directions, two kinds of following electrode structures and structure arrangements were formed in one pixel of the active matrix substrate.

i) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side many circular or polygonal holes (no transparent electrodes in a portion of a hole) are formed.

ii) A transparent flat common electrode is used in a color filter substrate side, and for transparent pixel electrodes countering the transparent flat common electrode in the active matrix substrate side, patterns having a shape of a long and slender slit are formed, and a liquid crystal alignment direction control electrode having almost the same shape as a shape of the slit, and a larger dimension than a dimension of the slit are formed in a lower layer of the slit via an insulated film.

iii) In a pixel of  $n$  row  $m$  column, a thin film transistor element is formed on a scan signal wiring of  $(n-1)$  row, a common electrode of  $n$  row and a liquid crystal alignment direction control electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element, and a thin film transistor element is formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the video signal wiring of  $m$  column and a transparent pixel electrode used for a pixel of  $n$  row  $m$  column are connected via the thin film transistor element.

[Method 26]

5 In the methods 22, 23, 24, and 25, a time width of a scan signal waveform in the scan signal wiring is no less than two times of a horizontal period, a scan signal waveform in a scan signal wiring of (n-1)th row and a scan signal waveform in a scan signal wiring of (n)th row overlap one another by no less than one time of a horizontal period; and polarities of a video signal voltage of a video signal wiring of m column, and a video signal voltage of a video signal wiring of (m+1) column are different from each other, 10 and the polarities being mutually exchanged every horizontal period, and the polarities being mutually exchanged every vertical period.

[Method 27]

15 In the methods 22 and 24, a channel length ( $L_2$ ) of a thin film transistor element that is formed in a position where a scan signal wiring of (n-1) row and a video signal wiring of column (m+1) intersect, and is connected with the liquid crystal alignment direction control electrode was set larger than a channel length ( $L_1$ ) of a thin film transistor 20 element that is formed in a position where a scan signal wiring of n row and a video signal wiring of m column intersect, and is connected with the transparent pixel electrode ( $L_1 < L_2$ ).

[Method 28]

25 In the methods 23 and 25, a channel length ( $L_2$ ) of a thin film transistor element that is formed on a scan signal wiring of (n-1) row, and is connected with the liquid crystal alignment direction control electrode was set larger than a channel length ( $L_1$ ) of a thin film transistor element 30 that is formed in a position where a scan signal wiring of n row and a video signal wiring of m column intersect, and is connected with the transparent pixel electrode ( $L_1 < L_2$ ).

[Method 29]

35 In the methods 22, 23, 24, and 25, a double transistor element structure or an offset channel element structure was

used for a thin film transistor element connected with the liquid crystal alignment direction control electrode.

[Method 30]

5 In the methods 22 and 23, a slit formed in the transparent pixel electrode in the active matrix substrate side and extending long and slender, and a slit forming a group with the liquid crystal alignment direction control electrode are arranged alternately, maintaining a relationship almost parallel to each other in an angle direction of about  $\pm 45$  degrees to an extending direction of the scan signal wiring; polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 31]

20 In the methods 22 and 23, a slit formed in a transparent pixel electrode in the active matrix substrate side and extending long and slender are arranged in a parallel direction and in a perpendicular direction to an extending direction of the scan signal wiring; and a slit forming a group with the liquid crystal alignment direction control electrode is arranged in a angle direction of about  $\pm 45$  degrees to a direction of the scan signal wirings; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

30 [Method 32]

In methods 22 and 23, there was adopted a structure that a slit formed in the transparent pixel electrode in the active matrix substrate side and extending long and slender is arranged in a angle direction of about  $\pm 45$  degrees to an extending direction of the scan signal wiring; and a slit

forming a group with the liquid crystal alignment direction control electrode is arranged in a parallel direction and in a perpendicular direction to an extending direction of the scan signal wiring; and the liquid crystal alignment direction control electrode encloses a periphery of the transparent pixel electrode while overlapping with the transparent pixel electrode via the insulated film; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 33]

In methods 24 and 25, there was adopted a structure that a slit forming a group with the liquid crystal alignment direction control electrode is arranged in a direction perpendicular to a direction parallel to an extending direction of the scan signal wiring so that two or more circular or polygonal holes currently formed in the transparent pixel electrode in the active matrix substrate side may be surrounded; and the liquid crystal alignment direction control electrode encloses a periphery of the transparent pixel electrode while overlapping with the transparent pixel electrode via the insulated film; and polarization axes of two polarizing plates placed in exterior of a liquid crystal cell are arranged in a direction of the scan signal wiring and in a direction of the video signal wiring, and are arranged so that they may perpendicularly mutually intersect.

[Method 34]

In the methods 22, 23, 24, and 25, the liquid crystal alignment direction control electrode formed in a lower layer of a slit of the transparent pixel electrode via the insulated film is simultaneously formed in the same layer at the time of formation of the scan signal wiring.



[Method 35]

5 In the methods 22 and 23, the liquid crystal alignment direction control electrode formed in a lower layer of a slit of the transparent pixel electrode via the insulated film is simultaneously formed in the same layer at the time of formation of the video signal wiring.

[Method 36]

10 In the method 22, two thin film transistor elements are required in one pixel in order to drive the one pixel and only one contact hole exists for electrically connecting a drain electrode of a thin film transistor element formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the transparent pixel electrode.

15 [Method 37]

20 In the methods 22 and 24, two thin film transistor elements are required in one pixel in order to drive the one pixel and two contact holes exist for electrically connecting a drain electrode of a thin film transistor element formed in a position where a scan signal wiring of  $(n-1)$  row and a video signal wiring of  $(m+1)$  column intersect with each other, and the liquid crystal alignment direction control electrode; and only one contact hole exists for electrically connecting a drain electrode of a thin film transistor element formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the transparent pixel electrode.

[Method 38]

30 In the methods 22, 23, 24, and 25, two thin film transistor elements are required in one pixel in order to drive the one pixel and one thin film transistor element is connected to the transparent pixel electrode, another remaining thin film transistor element is connected to the liquid crystal alignment direction control electrode, and

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the transparent pixel electrode and the liquid crystal alignment direction control electrode were overlapped via the insulated film to form a capacitance.

[Method 39]

5           In the methods 22, 23, 24, and 25, an intermediate electrode of a thin film transistor element connected with the liquid crystal alignment direction control electrode and having a double transistor structure and the transparent pixel electrode overlap via the insulated film to form a  
10           capacitance.

[Method 40]

          In the methods 22 and 24, a transparent pixel electrode of n row and m column and a scan signal wiring of (n-1)th row may overlap one another via an insulated film to form a  
15           storage capacitor.

[Method 41]

          In the methods 23 and 25, a transparent pixel electrode of n row and m column and a common electrode of n row may overlap one another via the insulated film to form a storage  
20           capacitor.

          Use of the methods 1, 2, 3, 4, 5, 6, 7, and 8, enables anisotropic liquid crystal molecules having a negative dielectric constant in a state of being vertically aligned to tilt in a target direction, as shown in Fig. 2, Fig. 3,  
25           Fig. 5, and Fig. 6.

          This makes unnecessary formation of a bump 5 that had to be formed on a color filter side substrate of a vertically aligned mode liquid crystal display, for motion directional control of liquid crystal molecules, as is shown  
30           in conventional method Fig. 1. Moreover, this enables manufacture of a multi-domain vertically aligned mode liquid crystal display using a cheap color filter, as shown in Fig.  
4.

          Furthermore, only alignment layers 6 and 7 and  
35           anisotropic liquid crystal molecules having a negative

dielectric constant 14 exist between a flat common electrode 4 in a color filter side, and a transparent pixel electrode 8 of an active matrix substrate as shown in Fig. 4, which completely solves problems, such as diffusion of contaminants from the bump 5, and remarkably improves reliability.

Additionally, even in case of failure in application of an alignment layer, omission of bump 5 enables simple and short time regeneration with oxygen plasma by a dry-asher. That is, in surface treatment process before alignment layer application, a plasma treatment with oxygen and argon using a dry-asher becomes usable, which remarkably decrease repelling and generation of pinhole in alignment layer application process.

Use of the methods 9, 10, 11, 12, and 13 may sharply improve effective use efficiency of polarizing plates, and thereby may reduce a cost of polarizing plates used for very large-sized liquid crystal displays. In addition, effective use efficiency of a polarizer having reflexivity comprising multilayer laminated body of two kinds of materials used for a backlight may also be sharply improved, which may also reduce cost of a backlight for very large-sized liquid crystals display. Moreover, possibility of control for a motion direction of liquid crystal molecules in four directions may provide wide viewing angles.

Use of the methods 14 and 15 enables manufacture of an active matrix substrate of the present invention using completely same processes, without changing manufacturing processes of conventional active matrix substrate.

In addition, since a liquid crystal alignment direction control electrode is arranged close to both sides of a video signal wiring and, as shown in Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 14, Fig. 16, Fig. 17, Fig. 18, and Fig. 25, a potential variation of a video signal wiring is easily

shielded, which may completely control a cross talk generation in a perpendicular direction.

5        Use of the methods 16, 17, 18, 19, and 20 enables separate drive for every row of liquid crystal alignment direction control electrodes currently formed in a lower layer of slits of transparent pixel electrodes of each row, enabling uniform display by same conditions in all portions of upper part, central part, and lower part of a display screen.

10        Use of the methods 2, 4, 6, 8, and 21 enables anisotropic liquid crystal molecules having a negative dielectric constant in a state of being vertically aligned to tilt in a target direction, preventing generation of disclination to enable uniform half tone display.  
15        Additionally, use of the method of the present invention may sharply improve a late response speed, in a change to a half tone display from a black display, and to a half tone display from a white display, that has been a problem in a conventional vertically aligned mode liquid crystal display mode. In case of responding animated pictures, increase of  
20        a bias voltage impressed between a certain transparent pixel electrode and a liquid crystal alignment direction control electrode formed in a lower layer of slits of the transparent pixel electrode may further improve a speed of  
25        response. In the present invention, since a display approaches closer to black display and the above-mentioned bias voltage may become larger, a speed of response is improvable in all regions.

30        Use of the methods 22, 23, 24, 25, and 26 makes unnecessary formation of a bump 5 in a color filter (CF) substrate 3 for motion directional control of liquid crystal molecules as is shown in Fig. 1 of conventional methods, which may enable a simple color filter structure as is shown in Fig. 34, Fig. 40, Fig. 45, and Fig. 46 to realize low  
35        price. Furthermore, a problem of diffusion into liquid

crystals of contaminant from bumps, which conventionally has been a problem, may completely be solved, and also a problem of unevenness in a half tone area induced from heterogeneity of shape of the bumps may completely be wiped away, leading to simultaneous realization of remarkable improvement in yield, and improvement in reliability.

Moreover, since a method of the present invention does not require bumps, in failure in application of an alignment layer, regeneration can be easily performed in a short time using oxygen plasma by a dry-asher. In surface treatment process before alignment layer application, a plasma treatment with oxygen and argon using a dry-asher becomes usable, which remarkably decrease repelling and generation of pinhole in alignment layer application process.

Use of the methods 22, 23, 24, 25, 26, 27, 28, 29, and 39 makes unnecessary special drive ICs for driving liquid crystal alignment direction control electrodes, and contact button parts, which may realize low price products. Furthermore, use of a double transistor structure, or an offset transistor structure may reduce leakage current. Since electric field is dispersed and concentration is prevented, even if a large voltage is impressed between a source and a drain electrode of a transistor, shift of a threshold voltage ( $V_{th}$ ) of thin film transistors is reduced, leading to realization of a reliable liquid crystal panel. Increase in a channel length ( $L_2$ ) of thin film transistor elements connected to liquid crystal alignment direction control electrodes may reduce a leakage current.

Use of the methods 22, 23, 24, 25, 26, 30, 31, 32, and 33 may sharply improve effective use efficiency of a polarizing plate compared with conventional liquid crystal panels in TN (Twisted Nematic) mode, which may reduce a cost of a polarizing plate used in very large-sized liquid crystal displays. In addition, effective use efficiency of a polarizer having reflexivity comprising multilayer

laminated body of two kinds of materials (brand name: DBEF by 3M Inc.) used for a backlight may also be sharply improved, which may also reduce a cost of a backlight for very large-sized liquid crystal displays.

5           Since use of the methods 22, 23, 24, 25, 34, and 35 enables manufacture of active matrix liquid crystal panels of the present invention using same processes, without changing most of conventional manufacturing processes of an active matrix substrate and manufacturing processes of a color filter in TN mode, leading to demonstration of  
10           predominancy in respect of yield and low cost.

          Use of the methods 22, 23, 24, 25, 26, 36, 37, and 38 may realize vertically aligned mode liquid crystal display having a simplest structure. This method does not have  
15           excessive and unnecessary thin film transistor elements in one pixel, but an aperture ratio may be set large in the highest, being able to realize a bright display.

          Since use of the methods 22, 23, 24, 25, 26, 27, 28, 29, and 39 enables impression of a large voltage between a transparent pixel electrode and a liquid crystal alignment  
20           direction control electrode, deformation of an electric field for driving vertically aligned liquid crystal molecules may be set significantly large. This may improve a rate of reaction of the liquid crystal molecules, and even  
25           in moving image displaying, a flow of image and a residual image phenomenon are scarcely generated.

          When a scanning line of n row is set as OFF, use of the methods 22, 23, 24, 25, 40, and 41 may decrease a potential variation of a transparent pixel electrode, and reduce  
30           flicker.

          Use of the methods 22, 23, 24, 25, and 26 may provide vertically aligned liquid crystal molecules with alignment almost perpendicular in all areas at the time of black display, which reduces light leakage more than in



conventional methods using bumps, and may realize completely uniform black display also in a dark room.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5           Fig. 1 shows a cross section structural figure of a conventional multi-domain vertically aligned mode liquid crystal panel;

          Fig. 2 shows a motion direction of molecules of anisotropic liquid crystal having a negative dielectric constant vertically aligned by an electric field formed with a flat electrode and a slit electrode;

10           Fig. 3 shows a motion direction of molecules of anisotropic liquid crystal having a negative dielectric constant vertically aligned by an electric field formed with a flat electrode, a slit electrode, and liquid crystal alignment direction control electrode;

15           Fig. 4 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20           Fig. 5 shows a drive principle cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention (when a pixel electrode has negative data);

          Fig. 6 shows a drive principle cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention (when a pixel electrode has positive data);

25           Fig. 7 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

30           Fig. 8 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 9 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

5 Fig. 10 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

10 Fig. 11 shows a waveform chart of a voltage impressed to a thin film transistor element of an odd number column of (n)th row and (n+1)th row of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 12 shows a waveform chart of a voltage impressed to a thin film transistor element of an even number column of (n)th row and (n+1)th row of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

15 Fig. 13 shows a plan view of contact button parts of scanning lines and liquid crystal alignment direction control electrodes of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20 Fig. 14 shows a plane structural figure of a vertically aligned mode liquid crystal panel of the present invention;

Fig. 15 shows a plan view of a vertically aligned mode active matrix substrate of the present invention;

25 Fig. 16 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 17 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

30 Fig. 18 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

35 Fig. 19 shows a plan view of contact button parts of scanning lines and liquid crystal alignment direction control electrodes of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 20 shows a plan view of a vertically aligned mode active matrix substrate of the present invention;

Fig. 21 shows a plan view of a vertically aligned mode active matrix substrate of the present invention;

5        Fig. 22 shows a waveform of a voltage impressed to a thin film transistor element corresponding to a pixel of an odd number column of (n)th row and of (n+1)th row of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

10       Fig. 23 shows a waveform of a voltage impressed to a thin film transistor element corresponding to a pixel of an even number column of (n)th row and of (n+1)th row of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

15       Fig. 24 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20       Fig. 25 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 26 shows a plan view of a vertically aligned mode active matrix substrate of the present invention;

Fig. 27 shows a plan view of a vertically aligned mode active matrix substrate of the present invention;

25       Fig. 28 shows a plan view and a cross section structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

30       Fig. 29 shows a plan view and a cross section structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

35       Fig. 30 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 31 shows a drive principle cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention (when a pixel electrode has negative data);

5        Fig. 32 shows a drive principle cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention (when pixel electrode has positive data);

10       Fig. 33 shows a waveform chart of a voltage impressed to a thin film transistor element of an odd number column (n)th row, and (n+1)th row of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

15       Fig. 34 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 35 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20       Fig. 36 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 37 shows a drive voltage waveform of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

25       Fig. 38 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

30       Fig. 39 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 40 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 41 shows a plane structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

5 Fig. 42 shows a plane structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

Fig. 43 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

10 Fig. 44 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 45 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

15 Fig. 46 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20 Fig. 47 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 48 shows a table showing potentials of A and B in the circuit model figure of Fig. 47;

25 Fig. 49 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 50 shows a table showing potentials of A and B in the circuit model figure of Fig. 47;

30 Fig. 51 shows a description of a flow of five-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 52 shows a description of a flow of four-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

35 Fig. 53 shows a description of a flow of five-photo-

mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 54 shows a description of a flow of four-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 55 shows a description of a flow of five-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 56 shows a description of a flow of four-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 57 shows a description of a flow of five-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 58 shows a description of a flow of four-photo-mask-process for a multi-domain vertically aligned mode liquid crystal panel manufacturing of the present invention;

Fig. 59 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 60 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 61 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 62 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 63 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 64 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;



Fig. 65 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

5 Fig. 66 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 67 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

10 Fig. 68 shows a cross section structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 69 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 70 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20 Fig. 71 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 72 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

25 Fig. 73 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 74 shows a circuit model figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

30 Fig. 75 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 76 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

5 Fig. 77 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 78 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

10 Fig. 79 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 80 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present  
15 invention;

Fig. 81 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

20 Fig. 82 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 83 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

25 Fig. 84 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 85 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present  
30 invention;

Fig. 86 shows a partial plan view of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 87 shows a plan view of an offset thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

5 Fig. 88 shows a sectional view of an offset thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

Fig. 89 shows a sectional view of an offset thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

10 Fig. 90 shows a sectional view of an offset thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

Fig. 91 shows a sectional view of a double gate thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

15 Fig. 92 shows a sectional view of a double gate thin film transistor element for multi-domain vertically aligned mode liquid crystal panels of the present invention;

20 Fig. 93 shows a plane structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

Fig. 94 shows a plane structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

25 Fig. 95 shows a plane structural figure of slits formed in a liquid crystal alignment direction control electrode and a transparent pixel electrode of the present invention;

30 Fig. 96 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 97 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

Fig. 98 shows a plane structural figure of a multi-domain vertically aligned mode liquid crystal panel of the present invention;

5 Fig. 99 shows a motion direction of molecules of anisotropic liquid crystal having a negative dielectric constant vertically aligned by an electric field formed with a flat electrode and a slit electrode;

10 Fig. 100 shows a motion direction of molecules of anisotropic liquid crystal having a negative dielectric constant vertically aligned by an electric field formed with a flat electrode, a slit electrode, and a liquid crystal alignment direction control electrode; and

15 Fig. 101 shows a motion direction of molecules of anisotropic liquid crystal having a negative dielectric constant vertically aligned by an electric field formed with a flat electrode, a slit electrode, and a liquid crystal alignment direction control electrode.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 Hereinafter, with reference to accompanying drawings, description about desirable Example of the present invention will be provided.

##### [Example 1]

25 Figs. 4, 5, and 6 show sectional views of Example 1 of the present invention. A color filter substrate 1 has a flat transparent common electrode 4, and an active matrix substrate 13 is arranged facing the substrate 1 and in parallel.

30 In the active matrix substrate 13, firstly, a scan signal wiring 17 and a liquid crystal alignment direction control electrode 15 are simultaneously formed in the same layer, and subsequently, a gate insulator film 12, an amorphous silicone layer, and an n<sup>+</sup> amorphous silicone layer for ohmic contacts are deposited.

After formation of a thin film transistor element part,  
a video signal wiring 11 and a drain electrode are formed.

Next, a contact hole 18 is formed in a portion of a  
drain electrode after deposition of a passivation film 10,  
and then a transparent electric conductive film is  
deposited. In the transparent electric conductive film, as  
shown in Fig. 7, some slits are formed and each pixel is  
completely separated for every pixel to provide a  
transparent pixel electrode 8.

An electrode structure of the present invention has  
following special features: there exist one another in one  
pixel a portion in which a long and slender slit 9, or a  
circular or polygonal hole is formed facing a flat  
transparent common electrode 4 on a color filter side, as  
shown in Fig. 2; and a portion in which a long and slender  
slit and a liquid crystal alignment direction control  
electrode 15 having almost the same shape as the slit, and  
having a larger dimension than a dimension of the slit are  
formed facing the flat transparent common electrode 4 on a  
color filter side, as shown in Fig. 3.

As shown in Fig. 5 and Fig. 6, these two kinds of  
electrode structures control to tilt correctly anisotropic  
liquid crystal molecules having a negative dielectric  
constant 14 in two directions, four directions, or many  
directions, that is, in target directions within one pixel.  
Distribution of equipotential lines is shown in Fig. 2 and  
Fig. 3.

As shown in Fig. 4, Fig. 5, and Fig. 6, in Example 1,  
liquid crystal alignment direction control electrodes 15 are  
arranged close to both of right and left sides of a video  
signal wiring 11. Since the liquid crystal alignment  
direction control electrode 15 shields a signal voltage  
variation of the video signal wiring 11, effect of the video  
signal wiring 11 is not transmitted to the transparent pixel  
electrode 8. As compared with conventional vertically

aligned mode liquid crystal displays shown in Fig. 1, a vertically aligned mode liquid crystal display of the present invention of Fig. 4 generates very little perpendicular stroke. Since a width of BM (shading film (Black Matrix)) 2 of a color filter may also be set more  
5 narrowly than in conventional products, a vertically aligned mode liquid crystal display with a large aperture ratio may be realizable.

[Example 2]

10 Fig. 30, Fig. 31, and Fig. 32 show sectional views of Example 2 of the present invention. In fundamental aspect, almost the same structure as in Example 1 is used for Example 2. An electrode structure of the Example has special features that two kinds of electrode structures as  
15 shown in Fig. 2 and Fig. 3 exist together in one pixel.

As shown in Fig. 30, Fig. 31, and Fig. 32, since a video signal wiring 11 is only sandwiched by transparent pixel electrodes 8 from both of right and left sides, capacitance of a video signal wiring 11 can be designed  
20 minimal, and accordingly, even if a resistance of the video signal wiring 11 is high, a problem of signal delay is hard to be generated.

Fig. 24 shows a plan view of Example 2. Only one row of liquid crystal alignment direction control electrode 15  
25 exists in one pixel. Adjacent transparent pixel electrodes 8 are connected to a thin film transistor element 16 controlled by a different scan signal wiring 17, respectively.

As a plan view of Fig. 24 shows, since an area in which the liquid crystal alignment direction control electrode 15  
30 exists close to a scan signal wiring 17 is small, even if the scan signal wiring 17 and the liquid crystal alignment direction control electrode 15 are simultaneously formed in the same layer, a probability that a defect in which



electric short-circuit is provided by a connection of each other will occur is extremely small.

Slits 9 are formed in a direction parallel direction and a perpendicular direction to the scan signal wiring 17, and slits forming a group with a liquid crystal alignment direction control electrode 15 are extended in angle directions of  $\pm 45$  degrees to the scan signal wiring direction. Slits forming a group with a liquid crystal alignment direction control electrode may have a form like connected diamond-shapes, and may have a form like squares located in a line as shown in Fig. 28 and Fig. 29.

[Example 3]

Fig. 7 shows a plan view of Example 3 of the present invention. The Example has a structure where two kinds of structures, a structure shown in a cross section structural figure of Example 1 and a structure shown in a cross section structural figure of Example 2, are mixed inside one pixel. In one pixel, two rows of liquid crystal alignment direction control electrodes of an upper liquid crystal alignment direction control electrode 19 and a lower liquid crystal alignment direction control electrode 20 are arranged, each potential is set as positive electrode potential and negative electrode potential on the basis of a potential of a counteracting flat common electrode 4 of a color filter side substrate. Adjacent transparent pixel electrodes 8 are controlled by a different liquid crystal alignment direction control electrode, respectively.

Fig. 11 and Fig. 12 show a transparent common electrode potential 21, a video signal wiring waveform 22 of odd number column, a scanning line signal waveform 23 of n row, a scanning line signal waveform 24 of (n+1) row, an upper liquid crystal alignment direction control electrode signal waveform 25 of n row, a lower liquid crystal alignment direction control electrode signal waveform 26 of n row, an upper liquid crystal alignment direction control electrode

signal wave form 27 of (n+1) row, a lower liquid crystal alignment direction control electrode signal wave form 28 of (n+1) row, and a video signal wiring waveform 29 of even number column.

5           As shown in Fig. 11 and Fig. 12, when a signal having a positive polarity is written in a transparent pixel electrode 8, a potential of a liquid crystal alignment direction control electrode currently formed via an insulator film 12 in a lower layer of a slit 9 of the transparent pixel electrode 8 has a positive polar potential  
10 higher than a potential of the transparent pixel electrode 8, and when a signal having a negative polarity is written in the transparent pixel electrode 8, a potential of a liquid crystal alignment direction control electrode  
15 currently formed via an insulator film 12 in a lower layer of a slit 9 of the transparent pixel electrode 8 has a negative polar potential lower than a potential of the transparent pixel electrode 8.

20           Transparent pixel electrode 8, and liquid crystal alignment direction control electrodes 19 and 20 of two rows arranged in one pixel have exchanged polarity, respectively, every perpendicular period.

25           As shown in Fig. 7, slits 9 currently formed in a transparent pixel electrode 8 and liquid crystal alignment direction control electrodes 19 and 20 arranged in a lower layer of the slit are arranged so as to make angles of  $\pm 45$  degrees to a direction of a scan signal wiring 17.

30           In an upper half and a lower half in one pixel, the slit 9 and the liquid crystal alignment direction control electrodes 19 and 20 of a lower layer of the slit, respectively, are arranged alternately and almost in parallel each other. Special feature is that a liquid crystal alignment direction control electrode is arranged in  
35 a central part of the pixel so as to divide the upper half and the lower half. Polarizing plates are arranged so that

polarization axes may become parallel and perpendicular to the scan signal wiring 17 and may have a relationship of intersecting mutually perpendicular, in an exterior of the liquid crystal cell.

5 [Example 4]

Fig. 8, Fig. 9, and Fig. 10 show a plan view of Example 4 of the present invention. This Example adopts a cross section structural figure of Example 1, and liquid crystal alignment direction control electrodes 19 and 20 enclose periphery of a transparent pixel electrode 8, which makes it difficult that the transparent pixel electrode 8 is influenced by a potential variation of a video signal wiring 11, and thus hardly generates a perpendicular cross talk. Moreover, since liquid crystal alignment direction control electrodes 19 and 20 and the transparent pixel electrode 8 are overlapped, a width of a shading film 2 of a color filter (BM) may be narrowed, and an aperture ratio may be increased.

In addition, liquid crystal alignment direction control electrodes 19 and 20 of two rows exist in one pixel, and thereby almost the same system as the drive system in Example 3 may be used.

In Fig. 8, slits 9 formed in the transparent pixel electrode 8 are arranged in directions of  $\pm 45$  degrees to a direction of the scan signal wirings. In Fig. 9, slits 9 formed in the transparent pixel electrode 8 are arranged in two directions perpendicular and horizontal to a direction of the scan signal wirings. In Fig. 10, fine notches of slit are formed in motion directions of liquid crystal molecules in the transparent pixel electrode 8. Arrangement of polarizing plates may be completely the same arrangement as an arrangement in Example 3.

[Example 5]

Fig. 14 shows a plan view of Example 5 of the present invention. This Example adopts a cross section structural

figure of Example 1, and liquid crystal alignment direction control electrodes 19 and 20 enclose periphery of a transparent pixel electrode 8, which makes it difficult that the transparent pixel electrode 8 is influenced by a potential variation of a video signal wiring 11, and thus hardly generates a perpendicular cross talk. This Example differs from Example 4 in a point that many circular holes 37 are formed in the transparent pixel electrode 8. As long as they are holes, polygonal forms may be of any kinds other than a circular form. Liquid crystal alignment direction control electrodes 19 and 20 of two rows exist in one pixel, and the same drive system as in Example 3 may be used. Arrangement of polarizing plates may be the same arrangement as an arrangement in Example 3.

[Example 6]

Fig. 16 shows a plan view of Example 6 of the present invention. This Example has a structure where two kinds, a cross section structural figure of Example 1 and a cross section structural figure of Example 2, are mixed inside one pixel. A liquid crystal alignment direction control electrode 15 of one row is arranged in one pixel, and adjacent transparent pixel electrodes 8 are connected, respectively, with a thin film transistor element 16 currently controlled by a different scan signal wiring 17. Forms of a long and slender slit 9 currently formed in the transparent pixel electrode 8 and of the liquid crystal alignment direction control electrode 15 currently formed in a lower layer of the slit via an insulator film 12 are almost the same as in Example 3, and are arranged to make angles of  $\pm 45$  degrees to the direction of scan signal wiring 17.

In an upper half and a lower half in one pixel, the slit 9 and the liquid crystal alignment direction control electrode 15 formed in a lower layer of the slit, respectively, are arranged alternately and almost in

parallel each other. A liquid crystal alignment direction control electrode 15 is arranged that divides an upper half and a lower half in a central part of a pixel. Polarizing plates are arranged so that polarization axes may become parallel and perpendicular to the scan signal wiring 17 and may have a relationship of intersecting mutually perpendicular, in an exterior of the liquid crystal cell.

In all Examples of the present invention, a transparent pixel electrode 8, and liquid crystal alignment direction control electrodes 15, 19, and 20 overlap mutually via the insulator film 12, and form an additional capacity (storage capacitor). When a larger additional capacity is required, an overlapping area may be set larger. When a smaller additional capacity is required, an overlapping area may be set smaller. In an usual range, an overlapping width of about 2 micron (2 micrometers) provides a sufficient additional capacity.

Fig. 22 and Fig. 23 show a driving method of Example 6. A driving method of the Example differs from a driving method of Example 3 a little.

Fig. 22 and Fig. 23 show a transparent common electrode potential 21, a video signal wiring waveform of odd number column 22, a scanning line signal waveform of  $n$  row 23, a scanning line signal waveform of row  $(n+1)$  24, a video signal wiring waveform of even number column 29, and a scanning line signal waveform of  $(n-1)$  row 43.

In Example 3, there is used a method that adjacent transparent pixel electrodes 8 are controlled by the same scan signal wiring 17 in Example 3, and video signals having different polarity, respectively, are written in from a video signal wiring 11. In Example 6, there is used a method that adjacent transparent pixel electrodes 8 are controlled by a different scan signal wiring 17, and video signals having the same polarity are written in after a shift of one horizontal scanning-period from a video signal

wiring 11. As Fig. 22 and Fig. 23 show, when a positive signal is written in a transparent pixel electrode, a potential of a liquid crystal alignment direction control electrode has a positive polar potential higher than the transparent pixel electrode, and when a negative signal is written in the transparent pixel electrode, a potential of the liquid crystal alignment direction control electrode has a negative polar potential lower than the transparent pixel electrode. The transparent pixel electrode and the liquid crystal alignment direction control electrode reverse each polarity for every perpendicular period.

In all Examples of the present invention, it is possible to tilt molecules of anisotropic liquid crystal having a negative dielectric constant 14 in a target direction from a perpendicular direction by setting a potential difference between a transparent pixel electrode 8 and liquid crystal alignment direction control electrodes 15, 19, and 20. In this case tilt angle may only be one - two degrees from a perpendicular direction (90 degrees). Usually, a bias potential of no less than 4 - 5 V is impressed. When a high-speed response is required, it is necessary to set a tilt angle as no less than 10 degrees, and a bias potential of no less than 6 - 8 V is impressed in this case. When the present invention is used for a liquid crystal TV, it is effective to set a bias potential between a transparent pixel electrode 8 and liquid crystal alignment direction control electrodes 15, 19, and 20 larger. When the present invention is made to serve a double purpose for a viewing display for computers, and for a moving image displaying apparatus for TV, it is effective to perform a circuit design so that this bias potential may be variable. [Example 7]

Fig. 17 and Fig. 18 show plan view of Example 7 of the present invention. This Example adopts a cross section structural figure of Example 1, a liquid crystal alignment



direction control electrode 15 encloses a periphery of a transparent pixel electrode 8, which makes it difficult that the transparent pixel electrode 8 is influenced by a potential variation of a video signal wiring 11, and hardly generates a perpendicular cross talk. One row of liquid crystal alignment direction control electrode 15 exists in one pixel, and adjacent transparent pixel electrodes 8 are connected to a thin film transistor element 16 controlled by a different scan signal wiring 17, respectively. A driving method of this Example is same as in Example 6. Arrangement of polarizing plate is also same as in Example 6.

[Example 8]

Fig. 25 shows a plan view of Example 8 of the present invention. This Example adopts a cross section structural figure of Example 1, and a liquid crystal alignment direction control electrode 15 encloses a periphery of a transparent pixel electrode 8, which makes it difficult that the transparent pixel electrode 8 is influenced by a potential variation of a video signal wiring 11, and hardly generates a perpendicular cross talk. One row of liquid crystal alignment direction control electrode 15 exists in one pixel, and adjacent transparent pixel electrodes 8 are connected to a thin film transistor element 16 controlled by a different scan signal wiring 17, respectively. A driving method of this Example is same as in Example 6. Many circular holes are formed in the transparent pixel electrode 8. As long as they are holes, polygonal forms may be of any kinds other than a circular form. A rotatory polarization liquid crystal display mode may be realizable by blending one of chiral material of left-handed rotation or right-handed rotation to an anisotropic liquid crystal having a negative dielectric constant. In this case, a value of product of a liquid crystal cell gap  $d$  and a refractive index anisotropy  $\Delta n$  should just be in a range of 0.30 - 0.60 micrometer. Molecules of anisotropic liquid crystal having

a negative dielectric constant tilt aligning in a shape of a swirl, while performing a left slewing motion or a right slewing motion centering on a circular hole, can pass a light from a backlight from perpendicularly arranged polarizing plates.

[Example 9]

Fig. 20 shows a plan view of active matrix substrate of Example 9 of the present invention. Both of contact button parts of contact buttons 30, 33, and 36 of a scan signal wiring and contact buttons 38 and 39 of a liquid crystal alignment direction control electrode are gathered a in left side of a display screen. Fig. 19 shows an expansion plan view of the contact button part.

Fig. 13 shows an expansion plan view of a contact button part in the case where liquid crystal alignment direction control electrodes of two rows exist in one pixel. Fig. 13 shows an upper liquid crystal alignment direction control electrode contact button 31 of  $n$  row, a lower liquid crystal alignment direction control electrode contact button 32 of  $n$  row, an upper liquid crystal alignment direction control electrode contact button 34 of  $(n+1)$  row, and a lower liquid crystal alignment direction control electrode contact button 35 of  $(n+1)$  row. One scan signal wiring is sandwiched from both of upper side and lower side by liquid crystal alignment direction control electrodes of different rows. Polarity switching of upper-side and lower-side liquid crystal alignment direction control electrodes is simultaneously performed based on a timing as shown in Fig. 33, and thereby a potential variation of the scan signal wiring may be controlled minimal, which suppresses generation of horizontal periodic unevenness in a display screen. As Fig. 13 show, a short-circuit between contact buttons may be prevented by providing a distance between the contact buttons 30, 33, and 36 of the scan signal wiring, and

the contact buttons 31, 32, 34, and 35 of the liquid crystal alignment direction control electrode.

[Example 10]

5 Fig. 15 and Fig. 21 show a plan view of an active matrix substrate of Example 10 of the present invention. Contact buttons 30, 33, and 36 of a scan signal wiring and contact buttons 38 and 39 of a liquid crystal alignment direction control electrode are separately divided into left side and right side of a display screen, respectively. A driving method of this Example may be methods as shown in 10 Fig. 11 and Fig. 12, and may be a method as shown in Fig. 33. In Example of the present invention, since a distance between contact buttons is expandable by adopting arrangements shown in Fig. 15 and Fig. 21, a short-circuit 15 between contact buttons can be prevented. Furthermore, usual scan signal wiring drive IC in TN mode may be used, which enable cost reduction in development and production.

[Example 11]

20 Fig. 26 and Fig. 27 show a plan view of an active matrix substrate of Example 11 of the present invention. Contact buttons 30, 33, and 36 of a scan signal wiring and contact buttons 31, 32, 34, 35, 38, and 39 of a liquid crystal alignment direction control electrode are provided in both of right and left ends of a display screen, which 25 may solve easily a problem of delay of scan signal waveform, a largest problem when driving a large-sized liquid crystal display.

In addition, Fig. 15, Fig. 20, Fig. 21, Fig. 26, and Fig. 27 show a video signal wiring terminal area 40, a pixel circumference common electrode terminal area 41, and a 30 protection network 42 for static electricity countermeasure.

[Example 12]

Fig. 34, Fig. 35, and Fig. 38 show a sectional view, a model view, and a plan view of Example 12 of the present 35 invention. Fig. 51 and Fig. 52 show a manufacturing process

flow of a TFT (Thin Film Transistor) array substrate of Example 12 of the present invention. Fig. 63 and Fig. 64 show an expanded sectional view of the TFT array substrate.

Color filter substrate 1 has a flat transparent common electrode 4, and an active matrix substrate 13 is arranged in parallel countering this substrate 1. Although bumps 5 for controlling a motion direction of a liquid crystal are formed on a flat transparent common electrode 4 as shown in Fig. 1 in conventional liquid crystal panel in vertically aligned mode, a liquid crystal panel in vertically aligned mode of the present invention does not require such bumps.

In the active matrix substrate 1, after formation of the scan signal wiring 17, an insulator film 12 and an amorphous silicon layer (non doped layer) 65 and an n<sup>+</sup> amorphous silicon layer 66 for ohmic contacts are deposited. A video signal wiring 11, a drain electrode, and a liquid crystal alignment direction control electrode 15 are simultaneously formed in the same layer after formation of a thin film transistor element part. A thin film transistor element, a video signal wiring 11, a drain electrode, and a liquid crystal alignment direction control electrode 15 are possible to be prepared in the same layer simultaneously, using a half-tone exposure technique currently disclosed in Japanese Patent Laid-Open No.2000-066240. Fig. 64 shows a sectional view of a thin film transistor element and an active matrix substrate of Example 12 of the present invention using the half-tone exposure. In addition, Figs. 63 and 64 show a scanning line terminal area 64.

As shown in Fig. 38, in Example 12 of the present invention, a number of thin film transistor elements required in one pixel is only two. A transparent pixel electrode 8 of n row and m column is connected with a thin film transistor element 16 formed in a position where a scan signal wiring of n row 17 and a video signal wiring of m

column 11 intersect with each other, and a liquid crystal alignment direction control electrode 15 is connected with a thin film transistor element 49 formed in a position where a scan signal wiring of (n-1) row 17 and a video signal wiring of (m+1) column 11 intersect with each other. Two kinds of slits are formed in the transparent pixel electrode 8, and Fig. 99 and Fig. 100 show a cross section enlargement of the slits.

In a slit 9 of type in Fig. 99, when a voltage is impressed, vertically aligned liquid crystal molecules 14 tilt in directions shown in Fig. 99. In a slit of a type in Fig. 100, a liquid crystal alignment direction control electrode 15 is arranged via an insulator film on a lower layer of the slit. In a slit of a type in Fig. 100, when a voltage is impressed, vertically aligned liquid crystal molecules 14 tilt in directions shown in Fig. 100. Fig. 41 and Fig. 42 show modified methods of Fig. 99 and Fig. 100. Fig. 41 and Fig. 42 show an opening 59 currently formed in a transparent pixel electrode on a liquid crystal alignment direction control electrode 15. In Fig. 100, the liquid crystal alignment direction control electrode 15 has a larger size than that of a slit of the transparent pixel electrode 8, and overlaps each other via an insulator film. An important point of the present invention is a point that the transparent pixel electrode 8 and the liquid crystal alignment direction control electrodes 15 overlap one another via an insulator film 12 to form a capacitance.

Molecules of anisotropic liquid crystal having a negative dielectric constant 14 may be made to move in same directions as in Fig. 100 also in an electrode structure arrangement as shown in Fig. 101, in a planar structure as shown in Fig. 93, a transparent pixel electrode 8 and a liquid crystal alignment direction control electrodes 15 do not overlap one another, and a capacitance formed by the transparent pixel electrode 8 and the liquid crystal

alignment direction control electrode 15 is small, but problems will be caused if a drive system of the present invention is used.

5 As shown in Fig. 94 and Fig. 95, it is particularly important in a drive system of the present invention that a transparent pixel electrode 8 and a liquid crystal alignment direction control electrodes 15 overlap at least in some area via an insulator film.

[Example 13]

10 Fig. 40 and Fig. 43 show a sectional view and a plan view of Example 13 of the present invention. Fig. 53 and Fig. 54 show a manufacturing process flow of a TFT array substrate of Example 13 of the present invention. Fig. 61 and Fig. 62 show an expanded sectional view of the TFT array  
15 substrate.

A color filter substrate 1 has a flat transparent common electrode 4, and does not have bumps as in Example 12.

20 In an active matrix substrate 13, after a scan signal wiring 17 and a liquid crystal alignment direction control electrode 15 are first formed in the same layer simultaneously, an insulator film 12, an amorphous silicone layer 65 (non doped layer), and n<sup>+</sup> amorphous silicone layer 66 for ohmic contacts are deposited. A video signal wiring  
25 11 and a drain electrode are simultaneously formed after formation of a thin film transistor element part.

A thin film transistor element, a video signal wiring 11, and a drain electrode are possible to be prepared in the same layer simultaneously, using a half-tone exposure  
30 technique currently disclosed in Japanese Patent Laid-Open No.2000-066240. Fig. 62 shows a sectional view of a thin film transistor element and an active matrix substrate of Example 13 of the present invention using the half-tone exposure.



As shown in Fig. 43, in Example 13 of the present invention, a number of thin film transistor elements required in one pixel is only two. A transparent pixel electrode 8 of n row and m column is connected with a thin film transistor element 16 formed in a position where a scan signal wiring of n row 17 and a video signal wiring of m column 11 intersect with each other, and a liquid crystal alignment direction control electrode 15 is connected with a thin film transistor element 49 formed in a position where a scan signal wiring of (n-1) row 17 and a video signal wiring of (m+1) column 11 intersect with each other. In Example 12, since a drain electrode of this thin film transistor element and a liquid crystal alignment direction control electrode 15 are simultaneously formed in the same layer, these are connected automatically, but in Example 13, since a drain electrode of this thin film transistor element and a liquid crystal alignment direction control electrode 15 are not formed in the same layer, two contact holes 61 and 62 must be provided in order to electrically connect these two electrodes. Although existence of two thin film transistor elements 16 and 49 and one contact hole 56 was enough for Example 12, Example 13 requires two thin film transistor elements 16 and 49 and three contact holes 56, 61, and 62, as shown in Fig. 43.

[Example 14]

Fig. 34, Fig. 36, and Fig. 39 show a sectional view, a model view, and a plan view of Example 14 of the present invention. Fig. 55 and Fig. 56 show a manufacturing process flow of a TFT array substrate of Example 14 of the present invention.

Fig. 67 and Fig. 68 show an expanded sectional view of the TFT array substrate.

A color filter substrate 1 has a flat transparent common electrode 4, and does not have bumps as in Example 12.

In an active matrix substrate 13, after a scan signal wiring 17 and a common electrode 48 in an active matrix side are first formed in the same layer simultaneously, an insulator film 12, an amorphous silicone layer 65 (non doped layer), and n<sup>+</sup> amorphous silicone layer 66 for ohmic contacts are deposited. A video signal wiring 11 and a drain electrode are simultaneously formed after formation of a thin film transistor element part.

A thin film transistor element, a video signal wiring, a drain electrode, and a liquid crystal alignment direction control electrode are possible to be prepared in the same layer simultaneously, using a half-tone exposure technique currently disclosed in Japanese Patent Laid-Open No.2000-066240. Fig. 68 shows a sectional view of a thin film transistor element and an active matrix substrate of Example 14 of the present invention using the half-tone exposure.

As shown in Fig. 39, in Example 14 of the present invention, a number of thin film transistor elements required in one pixel is only two. A transparent pixel electrode 8 of n row and m column is connected with a thin film transistor element 16 formed in a position where a scan signal wiring of n row 17 and a video signal wiring of m column 11 intersect with each other, and a liquid crystal alignment direction control electrode 15 is connected with a thin film transistor element 50 formed on a scan signal wiring top 17 of (n-1) row. Although a structure of transparent pixel electrode 8 may also have forms as in Example 12 and Example 13, in Fig. 39, slits 9 formed in a transparent pixel electrode 8 are arranged horizontally and vertically to an extending direction of a scan signal wiring 17, and slits forming a group with the liquid crystal alignment direction control electrode 15 are arranged so as to make an angle of  $\pm 45$  degrees to an extending direction of the scanning line. Since a source electrode 69 of a thin film transistor element 50 formed on the scan signal wiring

17 of (n-1) row and a common electrode 48 of n row are not formed in the same layer in case of Example 14, two contact holes must be formed in order to electrically connect these two electrodes. Accordingly, like Example 13, Example 14  
5 requires two thin film transistor elements 16 and 50 and three contact holes 56, 57, and 58, as shown in Fig. 39.  
[Example 15]

Fig. 40 and Fig. 96 show a sectional view and a plan view of Example 15 of the present invention. Fig. 57 and  
10 Fig. 58 show a manufacturing process flow of a TFT array substrate of Example 15 of the present invention. Fig. 65 and Fig. 66 show an expanded sectional view of the TFT array substrate. A color filter substrate 1 has a flat transparent common electrode 4, and does not have bumps as  
15 in Example 12.

In an active matrix substrate 13, after a scan signal wiring 17, a common electrode 48, and a liquid crystal alignment direction control electrode 15 are first formed in the same layer simultaneously, an insulator film 12, an  
20 amorphous silicon layer (non doped layer) 65, and an n<sup>+</sup> amorphous silicon layer 66 for ohmic contacts are deposited. A video signal wiring 11 and a drain electrode are simultaneously formed after formation of a thin film transistor element part. A thin film transistor element, a  
25 video signal wiring 11, and a drain electrode are possible to be prepared in the same layer simultaneously, using a half-tone exposure technique currently disclosed in Japanese Patent Laid-Open No.2000-066240. Fig. 66 shows a sectional view of a thin film transistor element and an active matrix  
30 substrate of Example 14 of the present invention using the half-tone exposure.

As shown in Fig. 96, in Example 15 of the present invention, a number of thin film transistor elements required in one pixel is only two. A transparent pixel  
35 electrode 8 of n row and m column is connected with a thin

film transistor element 16 formed in a position where a scan  
signal wiring of  $n$  row 17 and a video signal wiring of  $m$   
column 11 intersect with each other, and a liquid crystal  
alignment direction control electrode 15 is connected with  
5 a thin film transistor element 50 formed on a scan signal  
wiring 17 top of  $(n-1)$  row. In Example 15, in order to  
electrically connect a source electrode 69 of the thin film  
transistor element formed on the scan signal wiring of  $(n-1)$   
row 17, and a drain electrode 70 with a common electrode 48  
10 and the liquid crystal alignment direction control electrode  
15, respectively, contact holes 57, 58, 71, and 72,  
respectively, must be provided. Accordingly, Example 15  
requires two thin film transistor elements 16 and 50 and  
five contact holes 56, 57, 58, 71, and 72 as shown in Fig.  
15 96.

[Example 16]

Fig. 37 shows a timing chart about drive waveform that  
is Example 16 of the present invention. This is a drive  
waveform for driving a vertically aligned mode liquid  
20 crystal display described in Examples 12, 13, 14, and 15.  
Here may be given an important aspect of the present  
invention that:

a scan signal waveform of a scan signal wiring of  $(n-1)$   
row (address signal width) 52 and a signal waveform of a  
25 scan signal wiring of  $n$  row (address signal width 55 have a  
time width of at least no less than twice of a horizontal  
period, and mutually overlap by a time width no less than  
one horizontal period; and a polarity of a video signal  
voltage of a video signal wiring of  $m$  column and a polarity  
30 of a video signal voltage of a video signal wiring of  $(m+1)$   
column have a polarity different from each other and have  
polarities mutually reversed every horizontal period.

Fig. 37 shows a common electrode potential 51, a video  
signal wiring of  $m$  column signal waveform 53, and a video  
35 signal wiring of  $(m+1)$  column signal waveform 54.

When a drive system of the present invention is used, charging may be enabled to a capacitance C2 of a circuit model figure (capacitance C2 is a capacitance formed when a transparent pixel electrode and a liquid crystal alignment direction control electrodes mutually overlap via an insulator film), when a signal waveform of a scan signal wiring of (n-1) row and a signal waveform of a scan signal wiring of n row mutually overlap, as shown in Fig. 47, Fig. 48, Fig. 49, and Fig. 50. Here, Fig. 48 shows a potential of a position shown by A and B in a circuit model figure of Fig. 47, and Fig. 50 shows a potential of a position shown by A and B in a circuit model figure of Fig. 49.

In Fig. 47 and Fig. 48 a liquid crystal alignment direction control electrode is connected with a thin film transistor element formed in a position where a video signal wiring of (m+1) column intersects a scan signal wiring of (n-1) row, a transparent pixel electrode is connected with a thin film transistor element formed in a position where a scan signal wiring of n row and a video signal wiring of m column intersect with each other. When both of scanning lines of (n-1) row and n row are addressed in case of a video signal wiring of m column having +7 V and a video signal wiring of (m+1) column having -7 V, the above-mentioned two thin film transistor elements operate, and a capacitance C2 is charged and potentials of A and B obtain +7 V and -7 V, respectively. After the scanning line of (n-1) row is closed, when a polarity of a voltage of the video signal wiring of m column is changed to -7 V from +7 V and a polarity of a voltage of the video signal wiring of (m+1) column is changed to +7 V from -7 V, since a thin film transistor element of n row is operating, a potential of A of capacitance C2 varies to -7 V from +7 V. Since a thin film transistor element of (n-1) row is not operating at this time, a potential of B of capacitance C2 varies to -21 V from -7 V. Next, when the scanning line of n row is

closed, in potential of pixel of n row m column capacitance C2, A is fixed to -7 V and B to -21 V.

5 Same operation is performed after one perpendicular period, and since a polarity of the signal voltage of video signal wiring of m column and a polarity of the signal voltage of video signal wiring of (m+1) column are reversed, in potential of capacitance C2 after one perpendicular period, A is fixed to +7V, and B to +21V. Such potential relationship occurs, thereby a distribution of equipotential line as shown in figure are realized, and a motion direction of liquid crystal molecules may be determined. Since a large electric field is generated between the transparent pixel electrode and the liquid crystal alignment direction control electrode, large motion speed of liquid crystal molecule may be realized.

10 In Fig. 49 and Fig. 50, a liquid crystal alignment direction control electrode is connected with a thin film transistor element formed on a scan signal wiring of (n-1) row, and a source electrode of this thin film transistor element is connected with a common electrode of n rows. A transparent pixel electrode is connected with a thin film transistor element formed in a position where a scan signal wiring of n row and a video signal wiring of m column intersect with each other. When both of scanning lines of (n-1) row and n row are addressed in case of a video signal wiring of m column having +7 V and a video signal wiring of (m+1) column having -7 V, the above-mentioned two thin film transistor elements operate, and a capacitance C2 is charged and potentials of A and B obtain +7 V and 0 V, respectively.

20 After the scanning line of (n-1) row is closed, when a polarity of a voltage of the video signal wiring of m column is changed to -7V from +7V and a polarity of a voltage of the video signal wiring of (m+1) column is changed to +7V from -7V, since a thin film transistor element of n row is operating, a potential of A of capacitance C2 varies to -7V



from +7V. Since a thin film transistor element of (n-1) row is not operating at this time, a potential of B of capacitance C2 varies to -14V from 0 V. Next, when the scanning line of n row is closed, in potential of pixel of n row m column capacitance C2, A is fixed to -7 V and B to -21 V.

Same operation is performed after one perpendicular period, and since a polarity of the signal voltage of video signal wiring of m column and a polarity of the signal voltage of video signal wiring of (m+1) column are reversed, in potential of capacitance C2 after one perpendicular period, A is fixed to +7 V, and B to +14 V. Such potential relationships occur, thereby a distribution of equipotential line as shown in figure may be realized, and a motion direction of liquid crystal molecules may be determined.

[Example 17]

Fig. 44, Fig. 59, Fig. 60, Fig. 45, and Fig. 46 show a plan view and a sectional view of Example 17 of the present invention. Fig. 53 and Fig. 54 show a manufacturing process flow of a TFT array substrate of Example 17 of the present invention. Fig. 61 and Fig. 62 show an expanded sectional view of the TFT array substrate.

A color filter substrate 1 has a flat transparent common electrode 4, and does not have bumps as in Example 12. A connection method of a liquid crystal alignment direction control electrode 15 and a thin film transistor element is completely same as in Example 13.

In Example 17, slits formed in a transparent pixel electrode 8 has different forms from that in Example 13, they comprise a form arranged at  $\pm 45$  degrees to a direction of the scan signal wirings, a form arranged horizontally or vertically, or a form having circular or polygonal openings 63, as shown in Fig. 44, Fig. 59, and Fig. 60. A liquid crystal alignment direction control electrode 15 encloses periphery of a transparent pixel electrode 8, as shown in

Fig. 44, Fig. 59, and Fig. 60, and the liquid crystal alignment direction control electrode 15 forming a group with a slit is arranged horizontally or vertically to a direction of a scan signal wiring 17.

5 [Example 18]

Fig. 69, Fig. 70, Fig. 71, Fig. 72, Fig. 73, and Fig. 74; and Fig. 77, Fig. 78, Fig. 79, Fig. 80, Fig. 83, Fig. 84, Fig. 85, Fig. 86; and Fig. 91 and Fig. 92 show a circuit model figure of Example 18 of the present invention, and a  
10 plan view and sectional view of a thin film transistor.

Here, C1 is a capacitance formed with a transparent pixel electrode 8 and a flat transparent common electrode 4 in a CF (color filter) substrate side; C2 is a capacitance formed with the transparent pixel electrode 8 and a liquid  
15 crystal alignment direction control electrode 15; C3 is a capacitance formed with the transparent pixel electrode 8 and a scanning line; C4 is a capacitance formed with an intermediate electrode 67 of a double thin film transistor, and the transparent pixel electrode 8; and C5 is a  
20 capacitance formed with the transparent pixel electrode 8, and a common electrode 48 in an active matrix substrate side.

As already described in Example 16 of the present invention, when a drive system of the present invention is  
25 used, since a voltage impressed between electrodes of a video signal wiring of (m+1) column connected with a thin film transistor element formed on a scan signal wiring of (n-1) row and a liquid crystal alignment direction control electrode reaches about 28 V at the maximum, a problem  
30 occurs that a leakage current between these two electrodes increases. Accordingly, in Example 18 of the present invention, a double transistor structure is adopted as a structure of a thin film transistor element that is formed on a scan signal wiring 17 of (n-1) row, and is connected  
35 with a liquid crystal alignment direction control electrode

15. As shown in Fig. 91 and Fig. 92, the double transistor structure has a channel length longer than usual single transistor element, and even if a high voltage is impressed between a source electrode and a drain electrode, it can suppress increase in a leakage current. When not using a double transistor structure, it is also effective for reduction of a leakage current to lengthen a channel length of a transistor. As shown in Fig. 61 or Fig. 65, a channel length ( $L_2$ ) of a thin film transistor element connected with a liquid crystal alignment direction control electrode is set larger than a channel length ( $L_1$ ) of a thin film transistor element connected with a transparent pixel electrode, and thereby a leakage current may be reduced.

As a method for reducing a leakage current between a source electrode and a drain electrode, offset transistor structure as shown in Fig. 88, Fig. 89, and Fig. 90 may also be conceivable. In this case, a thin film transistor structure of a planar structure as shown in Fig. 87 is adopted. Here, notation F in Fig. 88, Fig. 89, and Fig. 90 shows amount of offset of an offset thin film transistor element. Moreover, an etching stopper layer 68 is shown in Fig. 90.

[Example 19]

Fig. 41, Fig. 42, Fig. 94, and Fig. 95 show a plan view of Example 19 of the present invention. This Example relates to a form of a transparent pixel electrode 8 and a liquid crystal alignment direction control electrode 15 used for Examples 12, 13, 14, 15, and 17. Molecules of anisotropic liquid crystal having a negative dielectric constant 14 has a property to arrange a direction of extended shaft of liquid crystal molecules 14 in a direction extending lengthwise of a wedge of a transparent pixel electrode 8 when a voltage is impressed, generation of disclination may be suppressed by adopting a form of Example 19 of the present invention.

Generation of disclination has a tendency for a transmittance of a liquid crystal panel and also for a speed of response to be reduced. A seed of response and a transmittance may be improved by adopting a form of the present invention.

Besides, as structures of a thin film transistor element of the present invention, two kinds of structures as Fig. 97 and Fig. 98 show may be conceivable. A type shown in Fig. 97 has a structure arrangement that: in a pixel of  $n$  row  $m$  column, a thin film transistor element is formed in a position where a scan signal wiring of  $(n-1)$  row and a video signal wiring of  $(m+1)$  column intersect with each other, a video signal wiring of  $(m+1)$  column, and a liquid crystal alignment direction control electrode used for the pixel of  $n$  row  $m$  column are connected via this thin film transistor element; and a thin film transistor element is formed in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $m$  column intersect with each other, and the video signal wiring of  $m$  column, and a transparent pixel electrode used for the pixel of  $n$  row  $m$  column are connected via this thin film transistor element.

On the contrary, B type shown in Fig. 98 has a structure arrangement that: in a pixel of  $n$  row  $m$  column, a video signal wiring of  $m$  column and a liquid crystal alignment direction control electrode used for the pixel of  $n$  row  $m$  column are connected via a thin film transistor element in a position where a scan signal wiring of  $(n-1)$  row and a video signal wiring of  $m$  column intersect with each other; and a video signal wiring of  $(m+1)$  column and a transparent pixel electrode used for the pixel of  $n$  row  $m$  column are connected via a thin film transistor element in a position where a scan signal wiring of  $n$  row and a video signal wiring of  $(m+1)$  column intersect with each other. The present invention includes both of A type structure and B type structure.

Use of the present invention does not require use of color filter substrates with bumps or slits that have been used for conventional multi-domain vertically aligned mode liquid crystal displays, but enables reduction of cost.

5        In addition, it may also cancel simultaneously display unevenness induced by variation accompanying bumps or processing of slits, and extremely improves yield.

10       Furthermore, it suppresses problems of unevenness, or residual image (image burn-in) caused by diffusion of impurities in pigments of a color filter, or impurities in bumps from crevices of bumps or slits into liquid crystals, and thereby realizes extremely reliable vertically aligned mode liquid crystal displays.

15       Since possibility of reworking may easily be realized with oxygen plasma treatment irrespective of defects generation in a polyimide alignment layer application process, reduction of reworking costs may be realized.

20       Use of electrode structures, structure arrangements, and driving methods of the present invention may enable production of active matrix substrates having a large aperture ratio, and may provide bright viewing displays. Furthermore, since it may improve a speed of response of liquid crystal molecules, very large-sized liquid crystal TVs responding animated pictures may be realized. In  
25       addition, it may realize a uniform black display with little light leakage in a dark room as compared with conventional vertically aligned mode liquid crystal displays using bumps.

30